Some Trends in the Use of Gold for Electrical Contacts

K. E. Saeger and E. Vinaricky
DUDOCO K.G., Pforzheim, West Germany

To achieve reliability in operation combined with economy in fabrication it has become necessary to carry out extensive development work in several fields, including the design of contact parts, the development of new alloys and of highly automated production methods as well as the careful analysis of service requirements.

From the time of Benjamin Franklin's early experiments in the field of electricity gold has been one of the favourite materials for electrical contacts. Its chemical inertness—its extremely low tendency to form non-conducting surface films—makes gold an almost ideal contact material for applications in which high contact reliability at low electrical loads and low contact forces is required. For contacts in electronics and telecommunications this specification is quite typical and gold, especially in the form of gold-rich-alloys, has found widespread application in this field.

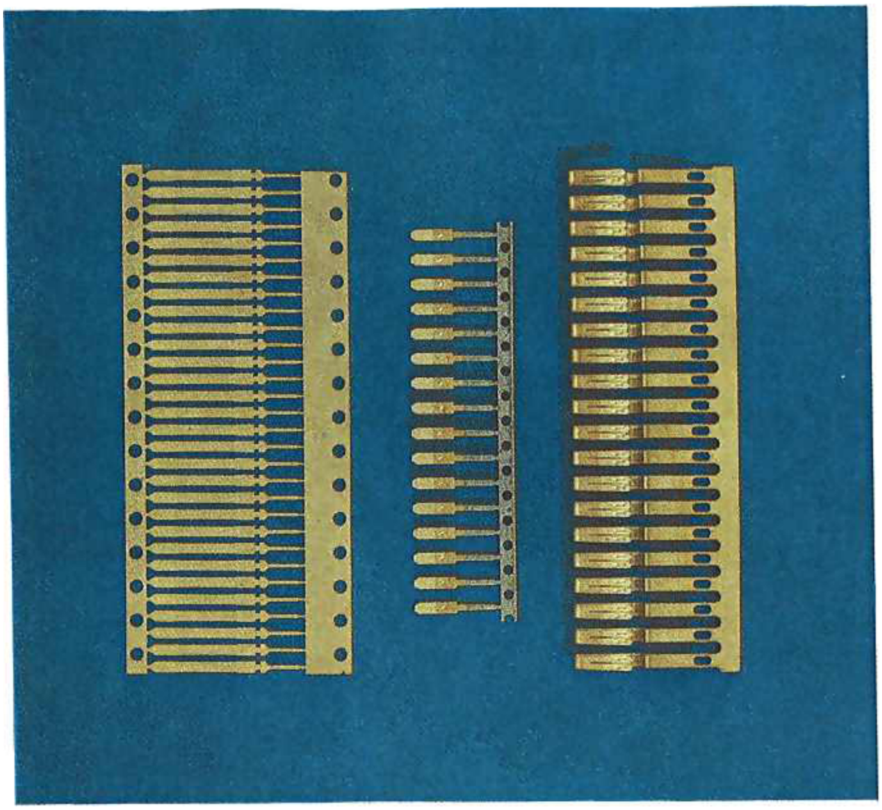
Reliability and Economics

The trend towards further miniaturisation of equipment and components has led to ever decreasing contact forces and also to decreasing electrical loads. Open-circuit voltages in the millivolt range, currents of a few milliamperes and contact forces of a few grams have now to be considered as quite normal. In such operating conditions it becomes impossible to break down tarnish films by electrical, thermal or mechanical means, and thus even minute quantities of corrosion products or other non-conducting matter may cause failure. On the other hand, the development of electrical and electronic equipment of increasing complexity and sophistication tends to demand extremely high standards of reliability for the contacts, as it does for all components. One further problem arises from the concurrence of a sharpened cost consciousness on the part of the manufacturer of electrical and electronic equipment and a rising gold price during the past few years. For this reason it has become quite important for the producer of electrical contact materials not only to provide materials which can meet the challenge of reliable long-term operation under less and less favourable conditions, but also to find technical solutions for the fabrication of contact parts which are satisfactory from the economic point of view. As the recent surveys on the future availability of raw materials show (1), this should go considerably beyond the solution of the problem of producing at competitive prices. Considerations on the economic use of gold should also include the aspect of stretching the limited supply of this valuable metal so that industry will be able to make use of the unique properties of gold and its alloys well into the future. These considerations have made it necessary to conduct extensive development work in several quite different fields. They comprise alloy development and production techniques as well as the design of contact parts and the careful analysis of service requirements.

Choice of Gold Alloys

Electrical contacts made of pure gold have a tendency towards sticking and cold welding even if only moderate contact forces are applied. In addition they are, in many cases, not sufficiently resistant to mechanical wear and to material transfer in dc operation. These problems have been solved by alloying the gold with one or more of the less noble metals. The choice of the alloying additions, as well as their quantity, has so far depended primarily on the type of application for which a certain contact part is intended. This has led to the development of a wide range of gold alloys containing up to about 30 weight per cent of metals such as silver, copper, nickel, cobalt, palladium or a combination of these; in some cases even cadium, zinc or indium have been added. A great wealth of information as to which alloys are particularly well suited for each application has been amassed over the years past and is available in the standard works of reference such as the books by Holm (2) and Keil (3). In the more recent past, however, an increasing effort has been devoted to the aspect of cutting costs

Efficiency in the production of connectors may be greatly increased in many cases if contact combs are used instead of single contact springs. The contact combs shown here are punched from inlaid bimetal strip consisting of a phosphor-bronze support with a contact inlay of a gold alloy containing 25 per cent silver and 5 per cent copper



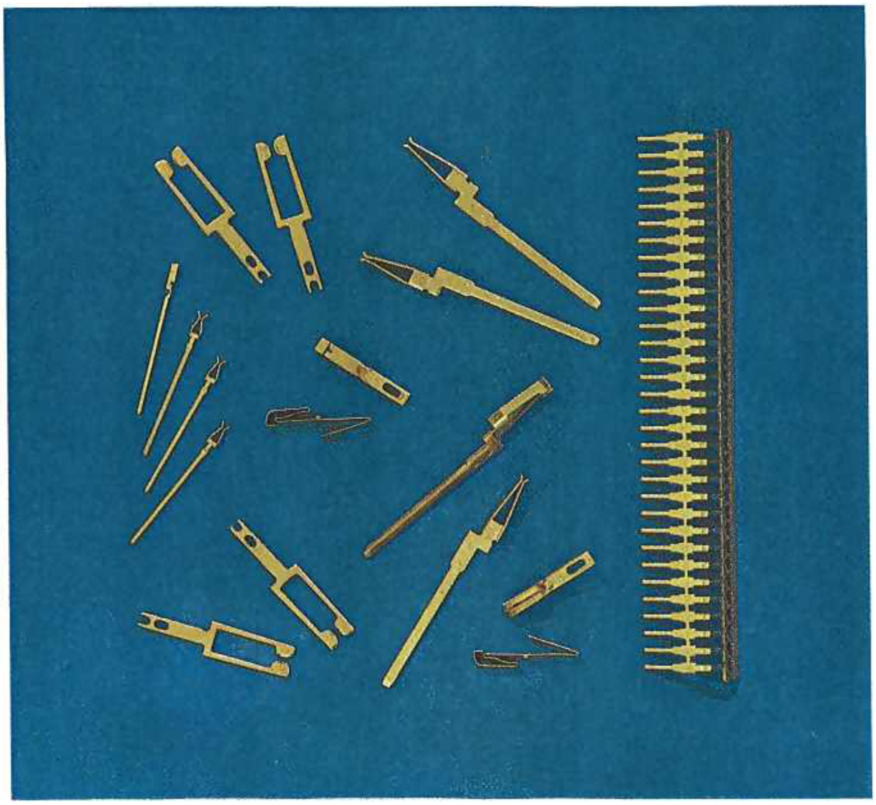
by substituting a substantial part of the gold content in contact alloys by less expensive metals.

The results of investigations (4) aimed at the elucidation of the corrosion and tarnishing behaviour of alloys with reduced gold content have shown that by using suitable combinations of metals it may be possible to obtain satisfactory tarnish resistance with gold alloys containing only about 55 to 60 weight per cent gold. On the other hand, however, these investigations tend to confirm the general experience that alloys of lower gold content are not sufficiently resistant to the formation of non-conducting tarnish films. Thus it has to be concluded that contents in excess of approximately 40 weight per cent of silver plus base metal cannot be tolerated if a very high standard of contact reliability has to be guaranteed. Substituting larger percentages of the gold content by other noble metals such as palladium, for instance, which would not seem unreasonable if one considers the present price per unit volume relations, does not yield a very satisfactory solution either. Palladium-rich contact materials operating under dry circuit conditions, i.e. in the millivolt/milliampere range, are sometimes found to fail because of the formation of organic polymer deposits ("brown powder") on the contact surface (5). This phenomenon is due to the catalytic action of the metals of the platinum group. It is observed if volatile organic materials are present, such as fumes emanating from insulating materials made of plastics or from the casings of modern relays, rotary switches or connectors.

The problems outlined above have been studied mainly on wrought alloys. As they are basically of a chemical nature, however, it should be expected that the conclusions drawn here are also, at least in principle, valid for gold alloys applied by means of electrodeposition, evaporation, or sputtering, even though additional complications may arise from the character of the microstructure of such gold deposits.

Limitations of Alloyed Gold Electrodeposits

The gold electrodeposits most frequently used in the field of electrical contacts are at present of the hard gold type, which means that they consist of 98 and more weight per cent gold with small additions of one or more metallic or non-metallic elements such as nickel, cobalt, copper, cadmium, or arsenic. For some special applications pure gold electrodeposits are used, for instance as very thin layers (usually about 0.2 microns thick) which are intended to ensure the solderability of silver contact parts during extended storage. Gold alloy electrodeposits with higher base metal contents, such as the 16 to 18 carat deposits used for decorative purposes, have found practically no application so far for electrical contacts because it has been felt that with these deposits an adequate contact reliability cannot be achieved. The reason for this lack of confidence



Electroplated contact springs for connectors punched from profiled beryllium-copper and phosphor-bronze strip. The strip is at first selectively electro-plated with a 2 μm nickel layer, then a 3 to 5 μm hard gold layer is applied in the contact region, and finally the parts receive a 0.5 μm gold flash over the entire surface

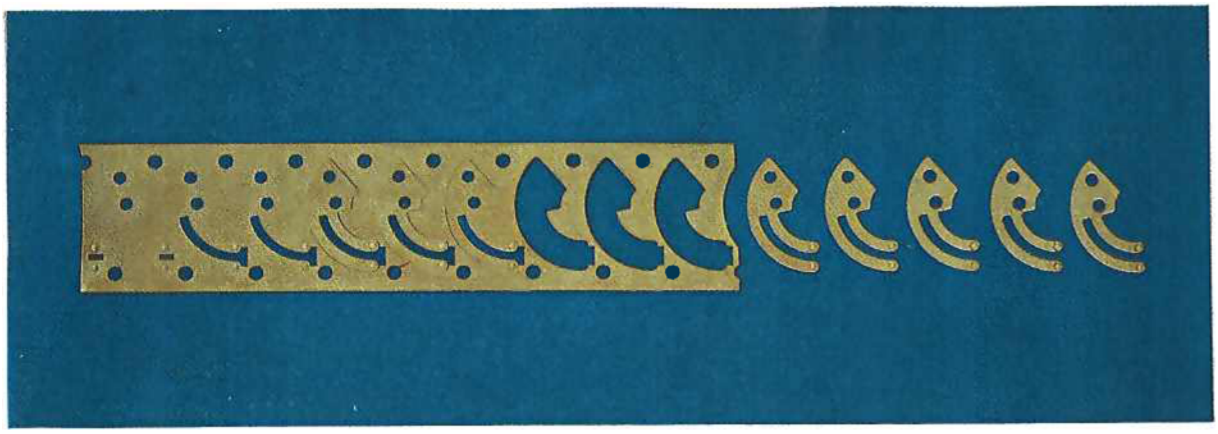
in the gold alloy electrodeposits containing larger amounts of base metals has been the results of early investigations into the structure of gold alloy electrodeposits (6). It was found, for instance, that the gold-copper electrodeposits were not homogeneous; according to X-ray structural analysis they consisted of regions of practically pure gold adjacent to regions of practically pure copper. It was concluded that there must be spots in these electrodeposits which show very much less resistance to corrosive attack than the overall composition of the deposit would suggest. This may, however, be not quite as critical as it has been believed, while on the other hand homogeneity of the gold alloy electrodeposits may not be a sufficient guarantee against corrosive attack.

Recent studies on gold alloy electrodeposits (7) indicate that even homogeneous gold-silver deposits containing 80 weight per cent of gold may not be suited for a number of applications in electrical engineering because they suffer a considerable increase in contact resistance after being exposed to sulphur-bearing atmospheres. The results of several investigations on ternary gold alloy electrodeposits are, however, more promising (7, 8, 9). They suggest that by providing suitable plating baths and plating conditions it may be possible to obtain gold alloy electrodeposits with markedly lowered gold contents which may be employed for electrical contact purposes, although it must not be expected that they will be able to replace the hard gold and fine gold types for all applications where very high standards of contact reliability have to be maintained.

Automated Production Processes

In the field of production technology the main emphasis has been put on the development of highly automated processes based on the method of punching the complete contact parts from continuous strip. This idea was introduced many years ago with the well known inlaid contact bimetal strip and has since found wide application. The strip material is usually produced by bonding a thick strip of the gold alloy most appropriate for the intended application into grooves cut into bars of the base metal support material (usually nickel-silver, phosphor bronze or some similar alloy with suitable mechanical properties) and then rolling this "bimetallic" assembly down to the required thickness. The present state of bimetal production allows the manufacture of material with inlays of widths down to about 2 mm and thicknesses in the vicinity of 1 μm. More recent developments have been in the direction of achieving a more economic use of the gold employed, and quite a variety of highly competitive methods have resulted.

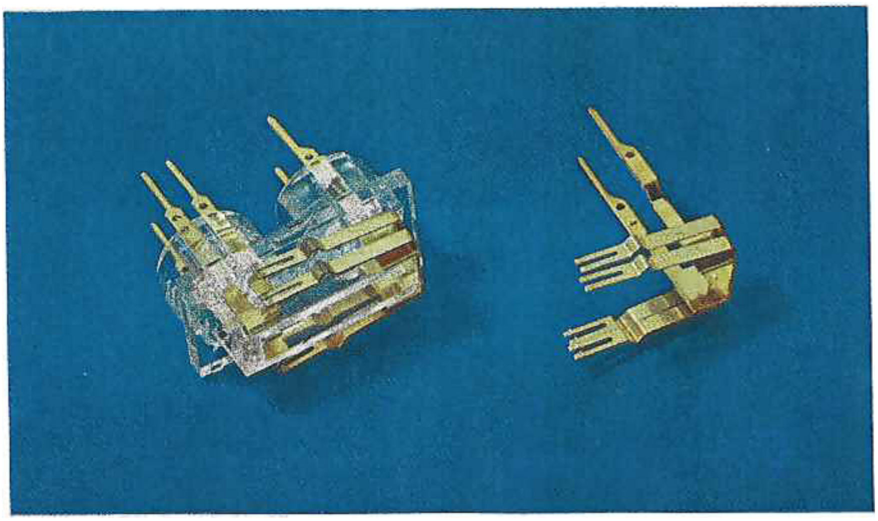
A typical example of these methods is the automatic welding of small balls (with a minimum diameter of



A sliding contact spring for multiswitches. This part is punched from phosphor-bronze strip on which the gold alloy contact material has been butt welded to the support in the form of small pieces of wire. These wires are then formed to the desired shape by means of an additional coining operation. The contact material is a 26 per cent silver-3 per cent nickel-gold alloy

0.25 mm) to support materials in the shape of practically continuous strip. The spherical form in which the contact material is supplied is relatively easy to produce and easy to handle in automatic feeding apparatus; furthermore, it makes it possible to apply only that quantity of the contact alloy that is needed for the actual point of contact. The whole cycle of operations, i.e. welding of the contact balls on to the support material, pressing the contact material into the desired shape, punching, bending and pressing of the blanks, can be carried out automatically in one suitably designed machine. Thus it is possible to produce contact parts in a great variety of designs from ordinary, commercially available semi-finished material. Quite similar to the technique outlined above is the butt welding of short lengths of wire to base metal strip material. Here the contact material is fed into the machine in the form of a continuous wire, thus eliminating the need for the production of the contact balls in a separate operation.

The advantages of the highly efficient automated manufacture of contact parts from strip material are also shared by the seam welding technique and by production from selectively electroplated strip. In the seam welding technique thin tapes or wires of the contact material are continuously welded to long lengths of strip material. Contact parts may be punched and formed from the welded profile sections thus produced in the same manner as from inlaid or onlay strip. An important advantage of the seam welded sections lies in the fact that it is possible to go to very small dimensions; gold alloy wires with diameters down to about 0.3 mm can be welded to spring hard support materials with thicknesses down to less than 0.1 mm. Furthermore it is possible, at the present stage of development of this technique, to weld thin bimetal or trimetal contact tapes to the supporting strip material. Thus contact parts for relays which have to switch dry circuits as well as load circuits can be produced from the same strip. In this case a contact tape consisting of a



A contact spring for a mechanically operated switch with digital display. The spring is produced from seam-welded beryllium-copper. The actual contact material in this case is again a gold alloy containing 26 per cent silver and 3 per cent nickel

thin gold layer on a palladium alloy is used. For the dry circuit part of the relays the gold layer guarantees a high contact reliability, while the load circuit, in which the formation of brown powder is less critical, is handled by the more erosion-resistant palladium alloy.

Selectively electroplated strip is preferredly used for applications where a thin layer on a relatively thick support material is needed such as, for instance, in the manufacture of connectors. One advantage of this selectively electroplated material is the fact that thin gold layers can also be applied to support material such as beryllium-copper or thermo-bimetals on which it is quite difficult to apply the contact material by any other method.

For the future it is foreseeable that even more stress will have to be put on the design of contact parts so as to arrive at solutions which combine efficient production techniques with minimum gold consumption for the intended service requirements. In this connection it may become necessary for many applications to reconsider the present requirements and fit them more closely to the expected service life of the other components in electrical and electronic appliances. In some cases this could mean that established quality standards will be lowered if detailed product analysis shows that the present requirements result in contact parts which last considerably longer than the other components. In other cases it may be useful to increase the projected service life of the contact parts even though this may lead to higher initial costs.

In the field of connectors and sliding contacts considerable research activity will have to go into the study of the mechanism of wear so that the service life of contact parts can be increased by minimising the losses of contact material due to wear. One typical example of this line of thought is the use of relatively thick nickel underlayers below quite thin gold layers. These nickel underlayers act not only as a very effective diffusion barrier for base metal atoms from the support material, which is most important for extended life at elevated temperatures, but also bring considerably improvements in the service life of a gold alloy layer of a given thickness (10, 11). Conversely this principle may, of course, be used to reduce the thickness of a gold deposit on a contact part intended for a given service life.

Parallel with detailed investigations into the mechanisms of wear the studies of the tarnishing behaviour of gold alloys will have to be intensified so that the probability of contact failure with contact alloys of reduced gold contact may be further decreased. For both fields of research a very close cooperation between contact manufacturers and producers of electrical and electronic appliances will be necessary in order to achieve optimum results, since the behaviour of contact materials is very often quite strongly dependent on the design of the devices in which they are used.

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The Wear of Electrodeposited Alloy Golds

A year ago J. W. Souter of Plessey Interconnect, Northampton, England, described an investigation of the wear characteristics of four types of gold electrodeposits as exhibited in a widely used forty-way plug and socket printed circuit connector (*Gold Bulletin*, 1974, **7**, (1), 12). In a further paper, presented to the International Electronic Packaging and Production Conference at Brighton, the author now reports on an extension of this investigation into the more complex methods of wear in four types of alloy gold deposits.

The wear resistance of a 17 per cent nickel-gold from an acid cyanide bath was found to be extremely good, but corrosion resistance was highly variable, with cracks penetrating to the basis metal. A 34 per cent silver-gold deposit from an alkaline cyanide electrolyte, despite a reasonably high hardness, showed very poor resistance to wear, resembling the behaviour of the sulphite golds previously reported.

The incorporation into a sulphite gold of 3 per cent copper and 5 per cent palladium greatly reduced galling and wear but the presence of copper naturally rendered the alloy prone to oxidation at around 125°C. The fourth type, a 34 per cent copper-gold alloy, also from a sulphite bath, showed similar wear characteristics to the palladium-copper-gold—local platelet stripping—but failed in corrosion testing although showing a lesser degree of attack than the silver-gold and nickel-gold alloys.

The author concludes that while copper is effective in improving the wear resistance of sulphite deposits it severely reduces the inherent corrosion and oxidation resistance of gold.